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FARM DRAINAGE

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Cover illustration. The tile drain outlet is made of a 20-foot length of 6-inch iron pipe from a junkyard. This is not likely to be damaged or to be dislodged by high water.

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Farm Drainage

By A. M. Goodman

Drainage is one of the most profitable ways to improve agricultural land, and one of the principal requirements of successful farming is productive soil. Soil that is nearly full of water during the early part, or throughout most, of the growing season cannot be highly productive, for crops cannot use the excess water in or on the soil; they can use only that which clings to the surface of the soil particles. Therefore, the most important step in soil improvement of cold soils is drainage, and tile draining wet spots in otherwise good fields is the most profitable form of drainage (figures 1 and 2).

Small wet spots were a nuisance when fields were worked with horses and hand labor; under present-day conditions, they are an expensive luxury. A good team of horses would take a plow or harrow through almost anything. A man sowing grain or putting in corn by hand was not stopped when he came to a wet place. He could throw some seed at the wet spot and walk around it. With tractor-drawn equipment, the farmer has to go around a wet spot so the machine will not get stuck in the mud. It costs much more to work around or through wet spots than it does to drain them. How much simpler and how much more time and fuel could be saved if the machine could go straight ahead. Furthermore, wet holes have never produced profitable crops. Thus the farmer pays for drainage whether he has it or not. If he does not drain these spots, he pays in loss of time, loss in production, and damage to machinery every year he works these fields. If he drains these places, he pays for the job only once.

The real cost of drainage has changed comparatively little during the past 50 years. It takes more dollars to drain wet spots now than it did in 1903, but it takes fewer bushels of corn, wheat, or beans, or pounds of milk or crates of eggs to pay for the work now than it did then. Many tile drains have paid for themselves in a single season, and they continue to return a profit long after the farmer pays for them.

General Effects of Drainage

The primary purpose of drainage is to lower the level of the ground water in the soil. This leaves the soil firm and warm, so it can be cultivated in season. This, however, is but one of the benefits of good drainage. Some others are the following:

Figure 1. A wet spot with cowslips and willows growing in and around it. Water and mud are knee-deep, and this spot is worse than useless. See figure 2.

1. Drainage admits air to the soil.

As the ground water is lowered, air enters the soil and fills the spaces that the excess water occupied between soil particles. Air is vital to the life and activities of the innumerable microscopic forms of animal and plant life which change the plant food in manure and crop residue into forms that the growing crops can use.

2. Properly drained soil warms early in the spring and thus assures a longer growing season.

Poorly drained soil is cold until late spring, because most of the water that gets away must evaporate. Evaporation of excess water from the soil requires just as much heat as that required to evaporate this same amount of water if it were in a great kettle over a fire. Heat used to evaporate excess soil water is completely wasted so far as the farmer is concerned. When excess water is removed by drainage, the heat from the sun can warm the soil. This warming and firming of the soil by drainage makes it possible to till and plant earlier, which insures better and quicker germi-

Figure 2. The same field as that shown in figure 1, fourteen months later

One line of tile through the low place made the difference. Good, uniform corn is growing where only brush and weeds grew before.

nation, stronger seedlings, and a longer growing period before the first killing frost.

3. **With the removal of excess water and the early development of crop plants, cultivation can be started early and can be done soon after rains.**

When seeds germinate quickly and seedlings are strong, the crops get "the jump" on the weeds. This makes it possible to follow the rows and to cultivate row crops sooner after planting. On well-drained soil, cultivation may follow summer showers much sooner than where the soil is poorly drained.

4. **With good drainage, crops are more resistant to the effects of drought.**

Roots of crops will not go into soil that is full of water. On well-drained soil, crop roots go deep for food and moisture; and when dry weather comes, these deep-rooted crops continue to draw nourishment from deeper levels. On the other hand, crops on soil that was wet early in the season develop only shallow, weak root systems. Such crops suffer badly and are stunted during even short periods of dry weather.

5. Drainage reduces heaving and makes land suitable for deep-rooted crops.

Poorly drained land heaves, due to the alternate freezing and thawing of the water that is in it. Alfalfa, birdsfoot trefoil, the clovers, and other deep-rooted crops planted during a favorable season on such land will be damaged and may be completely destroyed by fall, winter, or spring heaving.

6. Drainage facilitates drainage.

After land is drained, deep-rooted crops may be grown on it. When these crops die, their deep roots provide food for microscopic soil organisms and for other crops. As the roots decay, they leave passages in the soil through which excess water may pass downward and thus improve drainage. A beneficial cycle is thus established.

7. On properly drained fields, the farmer gets full use of modern labor-saving farm machinery.

In the Northeast, thousands of farms have relatively small wet spots in otherwise good fields. With the present-day complicated and costly tractor equipment, these spots cost more than any but the well-to-do farmer can afford.

Kinds of Drains

Open Drains

The principal uses of open drains or ditches are to carry off surface water after heavy rains, to carry the run-off from large areas, or to serve as outlets for tile-drainage systems.

Open drains and ditches are used extensively in the drainage of muck lands. Open ditches are sometimes used along the lower sides of sloping pasture and woodland to intercept the surface water from these areas and thus to prevent it from flowing out onto cropland. Such ditches, if deep enough, may also intercept the ground water that seeps out of the bases of hills and thus further protect cultivated fields. In such a place a better job, and one that requires much less maintenance, can be done by diverting the surface water with terraces[1] and by intercepting the ground water with a tile drain.

The size of open ditches naturally depends on their slope and the rate at which water may get to them. This rate, in turn, depends on the area and steepness of the land discharging water into them. It depends also on whether the soil is tight and absorbs water slowly or is permeable and absorbs much of the water falling on the land. The rate of run-off is further

[1]The location and construction of diversion terraces is discussed in Cornell Extension Bulletin 808, *Diversion Terraces,* by Hugh M. Wilson and Harry A. Kerr.

influenced by the cover on the soil. Water runs off more slowly from grass and woodland than from bare cropland or surfaces that have large exposed rock areas. Most drainage jobs need some open-ditch work.

So many and such different conditions affect the size of an open ditch that they should be planned by one familiar with the principles of design and who has had experience with such problems. Information concerning persons competent to make layouts and recommendations can be obtained from the County Agricultural Agent.

Open ditches may provide complete drainage, but they have several disadvantages. Of these, the following are the more important:

1. Open ditches deep enough to be effective cannot be crossed with tillage and harvesting implements and, therefore, except on land with a uniform slope, cut fields into irregular patches that are difficult and costly to cultivate with modern power machinery.

2. The ditches themselves, and the land required for machinery to turn at the end of crop rows, take a considerable part of the cropland out of productive use.

3. This turning near the ditches tends to compact the soil which retards the movement of ground water toward the ditches.

4. The cost to maintain open field ditches is high. The weeds and brush on the bottom, sides, and banks must be cut and deposits of silt must be removed each year to keep the ditch in operative condition. This takes time and labor; and, if not done regularly, the ditch soon becomes useless.

Under some conditions, grassed waterways make good open ditches. They are broad, shallow courses through depressions or along natural waterways. Their depth is so shallow and their side slopes so nearly flat that they may be crossed with farm implements and the grass on them may be harvested with the usual haymaking implements. To be effective, the side slopes must be carefully graded. The bottom and side slopes must be well fertilized and thoroughly seeded. Except on fairly steep slopes, it is good practice to mow the grass at least twice during the season.

If it is necessary to cross them during field operations, plows and cultivators must be lifted so as not to disturb the sod (page 35).

Subsurface Drains

Subsurface drains, also called *tile, blind,* or *underdrains,* are man-made underground channels through which excess water may flow to a suitable outlet. They in no way interfere with cultivation (figure 3).

Tile drains, as discussed here, include those made of burned clay as well as concrete tile and bitumenized-fiber pipes.

Figure 3. Cross-section of a tile drain

The improved condition of the land is all that is noticeable after the tile is laid and the trench filled.

The marked advantage of tile drains as compared with open field ditches is that they may be placed where needed without cutting the land into relatively small irregular fields. On most soils they are more effective than open field ditches. With tile drains, wet spots may be removed so the whole field can be fitted, planted, and cultivated, and the crop harvested when conditions are right for operations on the major part of the field (figure 4). Properly installed tile drains require little maintenance (page 43).

The sizes of tile for this purpose have inside diameters of 4, 5, or 6 inches, and are 1 foot in length. In larger sizes, the tile diameters are in even-numbered inches, as 8, 10, and 12, and are commonly made in lengths of 18 or 24 inches.

Bitumenized-fiber pipe for land drainage is available in 4- and 6-inch diameters, and these sections are either 4 or 8 feet long. This pipe has two rows of small holes through which the water may enter.

Tile drains are effectively used to intercept underground water that,

Figure 4. A wet spot in an otherwise good field

Note that the oats were drilled to and from the camera. Two weeks later several drill widths were planted around the pool. One line of tile drain would make it possible to plant the *whole* field early.

as it moves down slopes, may cause seepage spots (page 23). They are used to drain shallow depressions where water tends to stand until late in the spring or after heavy rains (page 22). They are used also to lower high-level ground water in large areas.

Three-inch tile is suitable only for use in rather dense soil and where the slope is 6 inches or more for each 100 feet of length. The trench bottom for these small tile should have a uniform slope and must be carefully graded. Even under these favorable conditions they are not recommended for lines more than 800 feet long.

In the past, the stone drains found on many farms were made in several ways. The two ways shown in figure 5 were the most usual. Their construction required much heavy hand labor. They had an earth bottom and a wide and relatively deep trench. Furthermore, it was necessary to find, haul, and lay suitable stones for the throat or waterway. In the process of clearing land, however, and when labor was relatively plentiful, they had a place in the farm economy. Under favorable conditions many gave years of good service. Others failed within a few years. Many of the so-called wet-weather springs in fields today are the result of old stone drains that have become blocked, forcing the water flowing to these stoppages to the surface. Because of the danger of stoppages, as well as the present scarcity and cost of farm labor, stone drains are no longer practical.

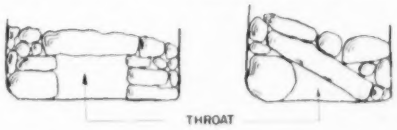

Figure 5. Cross-section of two common types of stone drains

A wide, deep trench and lots of suitable stones were needed. Skill and strength were required to build them.

Limitations of tile drainage

Well-made tile drains are effective in most of the reasonably good farm land of the Northeast. Some soils, however, are so tight or impermeable that the water passes through them too slowly to make these drains effective. Under such conditions, bedding (page 46) and other forms of surface drains are recommended.

Planning a Tile-drainage Line

Steps in Planning

Three important steps in planning a tile-drainage line are:

1. To find a promising outlet. This may be a good open ditch or a stream. A place where the bank is high enough to have the trench at least 2 feet deep and close to the end of the tile is best.

2. To measure the horizontal and vertical distances between the place to be drained and the proposed outlet, and thus to find the possibilities of drainage.

3. The last, but by no means the least, step is to find the source of the water to be removed. In general, the water will be in a low sag into which it has settled or it may come from a spring or from a seepage area on a slope.

The tile should have a free discharge when it is most needed; that is, in the spring and after heavy rains during the growing season. More thought must naturally be given to outlets into ditches or streams that have nearly level bottoms or beds where run-off after storms is slow.

Depth, Slope, and Spacing of Tile

For best results, the bottom of tiles that are to collect water should be from 2.5 to 3 feet below the surface of the ground. Deeper cuts may be needed in some parts of the line to insure the required slope. Seldom should tile be laid as shallow as 2 feet. Where, however, a line passes through a sag, the tile may safely be laid at this shallow depth. In such locations it will, because of surface washing and tillage, eventually become covered more deeply.

Tile drains that run down the slope collect water from only a narrow strip at either side of the drain. Lines that run across the slope are much more effective because they tend to intercept both surface and underground water as it moves downhill.

Where 4-inch tile is to be used, 0.3 of 1 per cent or from 3.5 to 4 inches fall to each 100 feet of length, should be considered the minimum. Seldom is it good practice to have the slope of tile that is to collect water steeper than 1½ per cent, or 1½ feet of fall for each 100 feet of length.

The best spacing of parallel tile lines used for a complete drainage system depends chiefly on the character of the soil and the crops to be grown. For the usual farm crops, 4 rods, or 66 feet, has, in general, proved satisfactory. For truck crops, where labor and fertilizer costs are high and early planting is exceedingly important, spacing the lines at half (2 rods) this distance may be more profitable.

As a general rule, lines may be farther apart and should be placed deeper in permeable soil than in more dense soil where the movement of water is slower.

If possible, the line of tile should have a uniform rate of slope. Unfortunately, this cannot always be had. The lower part of the tile line may, if necessary, be steeper than the upper part, but the lower part of the line should not be less steep than the upper part because the water would flow

less rapidly on the flatter slope and could deposit silt, which might eventually block the line. Such changes in slope may usually be avoided by running the line across sloping land rather than down the slope and across relatively level land. The use of larger tile on these flatter slopes prevents the build-up of pressure by water coming from the higher part of the line. Water under pressure in the tile may be forced up through the soil to the surface; such places are called *blow outs*. They may make holes in the field and even displace tile.

The use of tile of adequate size in this lower and more nearly flat part of the line and of *clean outlets* or catch basins (page 34), from which the water can readily escape, provide the best prevention against blow outs.

Layout of Lines of Tile

Short line

To illustrate a simple way to layout a short tile drainage line, consider a sag where water tends to collect. The cross-section, or profile, of such a sag and of a ditch into which it is proposed to outlet the tile is shown in figure 6.

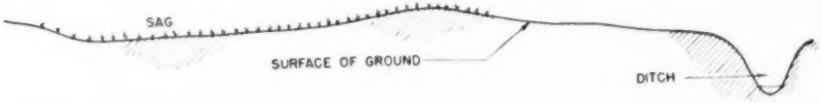

Figure 6. Cross section or profile showing, at left, a sag where water collects and, at right, a ditch into which the water might be drained
See figure 8.

With a tape, or by careful pacing, one can find the horizontal distance between the proposed outlet and the lowest place in the sag. This distance might, for example, be 375 feet.

The easiest way to find the difference in elevation or vertical distance between the lowest part of the sag and the surface of the water in the ditch is with a leveling rod and a level mounted on a tripod. If these are not available, a board about 2 inches wide and 8 or 10 feet long and a good carpenter's level may be used. Sights that clamp on the level (figure 7) may be purchased at hardware stores. They make sighting easier and more accurate.

Figure 7. A pair of sights which may be clamped to a carpenter's level, either wooden or metal

With this simple equipment, one can sight more easily and more accurately.

To find the difference in elevation, one places the level on a box about midway between the sag and the proposed outlet, and blocks the box up

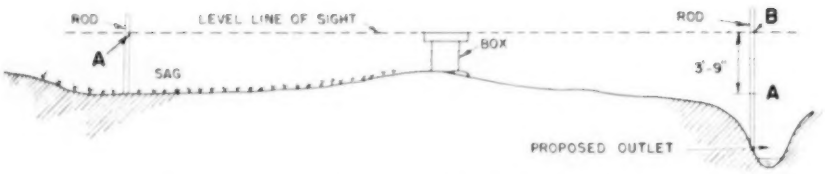

Figure 8. Level in position for sighting on rod in the lowest part of the sag (A) and at surface of water in the ditch (B)

so it is firm and level both ways. The rod or board is held in the sag. One sights over the level and has the person holding the rod mark the point *A* where the line of sight strikes the rod (figure 8). The rod is now held at the surface of the water in the ditch. The man at the level sights on the rod as before and has this point *(B)* marked also. He measures the distance between the marks *A* and *B*.

It is assumed that the second mark *(B)* is 3 feet and 9 inches farther up on the rod than the first mark *(A)*. This means that the bottom of the rod and, therefore, the surface of the water in the ditch where it was held is 3 feet 9 inches lower than where it was first held in the sag, for both marks were placed at the same level or elevation.

If the tile is to be laid 2 feet deep under the lowest place in the sag and ½ foot above the water surface in the ditch, there is 1 foot 3 inches, or 1.25 feet, available for slope in the length of the proposed tile [3′9″ − (2′0″ + 0′6″) = 1′3″]. Since the line is 375 feet long, the slope per foot is 0.00333 feet per foot (1.25 ÷ 375 = 0.00333) or 0.333 feet per 100 feet of length (0.00333 × 100 = 0.333 feet or 4 inches). From these simple observations and calculations, it is obvious that a tile line with satisfactory depth in the sag and enough slope can be installed. Such a line will also have a free outlet because the end of the tile is 6 inches above the water in the ditch.

While one can determine the horizontal distance fairly well by careful pacing, it is important to measure the vertical distance carefully and accurately. In this example an error of ½ inch in measuring the vertical distance would have the same effect as an error of 12 feet in the horizontal distance.

The next problems are (1) to determine how deep the trench must be at various points along the line and (2) to provide a way to get a uniform slope on the trench bottom. To do this, one firmly drives a stake *(H)* about 5½ feet long where the rod was first held in the sag (figure 9), braces this stake well, and puts a mark *(I)* on the stake 4 feet above the ground. This mark is 6 feet above the bottom of the proposed trench bottom which it has been decided will be 2 feet deep at this point.

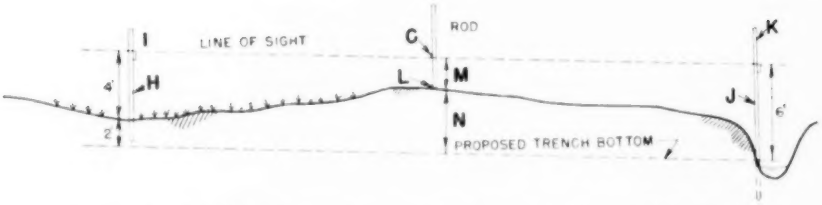

Figure 9. How to find the depth at any place along the proposed trench line

Then one firmly drives another well-braced stake *(J)*, 7 or 8 feet long, where the rod was held at the proposed outlet, and places a mark *(K)* on this stake 6½ feet above the surface of the water in the ditch. That is 6 feet above a point ½ foot above the water, where the tile is to come out. Both marks *I* and *K* are now 6 feet above the bottom of the proposed trench. Both stakes *H* and *J* are needed until the trench is completed and the tile is installed. One should not dislodge these stakes. It is good practice to nail short, level cross boards at *I* and *K* for convenience in sighting.

The line of sight from *I* to *K* is parallel to the proposed bottom of the trench and 6 feet above it. Therefore, the difference between the distance *M* and 6 feet is the depth *(N)* that it will be necessary to make the trench to give the tile an even or uniform slope. The depth that the trench will have to be at any point on the line can be found in this way.

Grade line

A grade line is needed to assure correct depth in every part of the trench and thus to have uniform slope. *A grade line is a tight string that is directly above, and parallel to, the proposed finished bottom of the trench.* For convenience, the grade line may be placed 6 feet above the trench bottom. Here (figure 9) a grade line 6 feet above the trench bottom coincides with the line-of-sight discussed in the preceding paragraph.

A grade line if not tight and not supported at reasonable intervals sags and is misleading. As supports, pairs of stakes may be set, one on either side of the proposed trench, and batter boards put on them (page

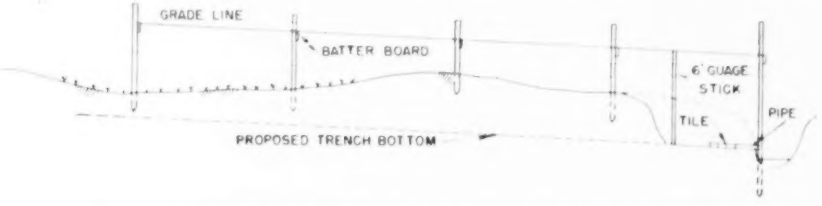

Figure 10. How to use a gauge stick to check exact depth of trench
Note the grade line.

39). The batter boards should be no farther apart than 50 feet. Their top edges may be sighted in between points *I* and *K*. The top of each batter board must be level from end-to-end. A *gauge stick* may be made from any long piece of wood and marked 6 feet from one end.

Figure 11. A tile drainage scoop

It can be set at various angles to the handle so the user may stand in the trench or on the bank.

To dig the light trench, one starts at the outlet and as the work progresses checks the depth. The 6-foot mark comes just to the grade line where the end of the gauge is on the trench bottom (figure 10). The gauge must be plumb. Care must be taken to insure that no part of the trench is made too deep. The tile scoop, or drain cleaner (figure 11), is a most useful tool with which to finish the trench bottom.

It is usually good practice to keep the laying of the tile and backfilling within a rod or so of the digging (page 19). When the job is done by contract, however, the farmer should insist that no one cover the tile until it has been inspected. He should, out of fairness to the contractor and himself, make this inspection promptly.

Where the line of tile passes through the sag, a permeable fill surface inlet (page 33) is needed so the water can get quickly to the tile.

The outlet end of the tile should be protected as suggested on pages 30 to 32.

Longer lines and branching systems

It is beyond the scope of this publication to discuss the survey of larger systems. A person who has neither equipment nor experience should consult the County Agricultural Agent who can do the job or arrange for the services of a competent person. The systems on most farms that have tile drainage are made up of several branches (figure 12), so any line installed in lower parts of the farm might some day act as a main. For this reason the farmer should be sure that the tile is large enough to carry the water from other parts of the farm that may be drained later.

Because of the importance of a good outlet and of the cost of its construction and maintenance, it is best to have as many lines as possible discharge

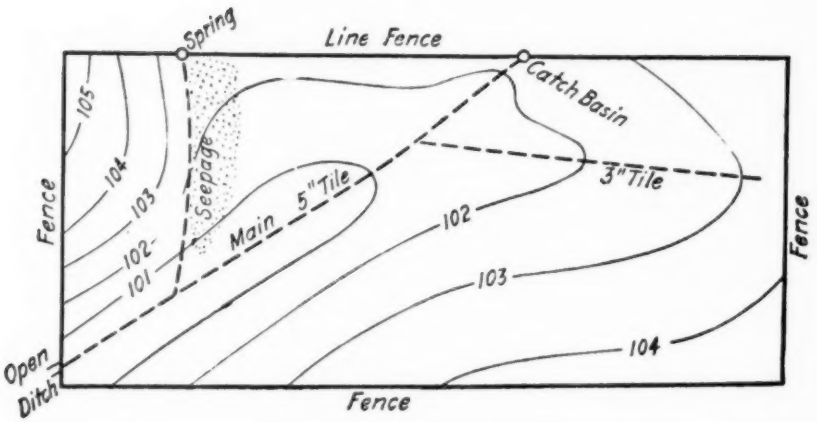

Figure 12. A branching tile system

The 5-inch main with catch basin was first installed. Then the two branches were connected to it. Each of the curving (contour) lines is at the same level throughout its length.

at one place (figure 13). The saving in the cost of making several outlets more than pays for the slightly longer tile lines and the few extra connections.

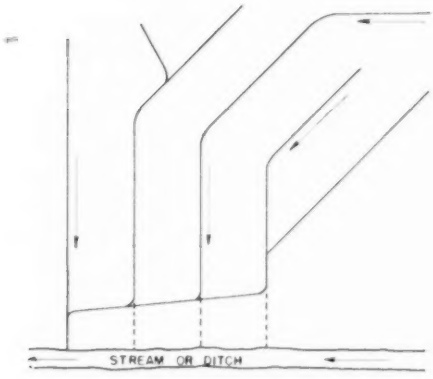

Figure 13. How to discharge several tile lines through one outlet

Figure 14. The tile hook

A man working from the trench bank may place tile in the trench with a hook like this.

Figure 15. A well-laid curve in a tile line

Note the smoothness of the curve and the close fitting joints.

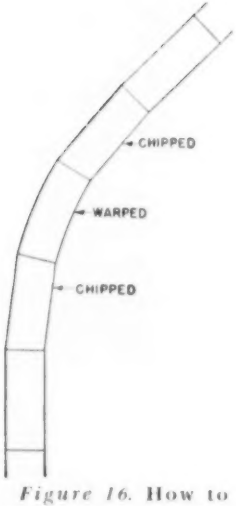

Figure 16. How to make a good curve with warped tile and with tile that has been chipped at the ends

Figure 17. The upper end of the tile line carefully blocked with a flat stone

Laying and Covering Tile

THE first step in laying tile is to have the ditch bottom carefully graded and finished (pages 15 and 16).

The tile may be laid by a man moving backwards in the trench or from the bank with a tile hook (figure 14). The line of tile should be kept as straight as the general direction of the trench permits (figure 15). Bends should be made in smooth curves. The individual pieces of tile may be turned so they will fit snugly together at the top. Except in fine, sandy subsoil (page 28) openings ¼ inch wide at the bottom, where most of the water enters, are, in general, not objectionable. For joints on curves, clay tiles that are slightly warped or have uneven ends may be turned to fit snugly (figure 16). Any joints at the top or sides of the line that are as much as ¼ inch wide should be carefully covered with pieces of broken tile or flat stones.

The upper end of the tile line must be carefully blocked with a stone (figure 17), so earth or burrowing animals can not get into it.

Binding and Blinding

As soon as the tile are laid, they should be bound by putting fine earth at either side to hold them. If the bottom of the trench is not rounded, the soil used for binding should be firmly tramped. After the line is bound, it should be blinded with a covering of surface soil that contains roots and other crop residue. This may be done by breaking in the shoulders of the trench banks with a spade, shovel, or mattock (figure 18). Stones should never be allowed to fall on the tile, for they might crack the tile. When the roots in the topsoil decay, they leave tiny passages through which the water finds its way to the joints in the tile. It is good practice next to turn in, with a plow, one or more furrow slices from each side of the trench. After this, the backfilling may be completed with a grader,

Figure 18. Breaking the sod and top soil from the trench shoulders to blind the tile

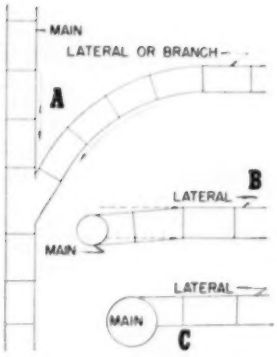

Figure 19. Practices (A, B and C) that tend to keep the water in the main flowing smoothly

A. The water from the lateral or branch tile is turned in the same direction as that flowing in the main.

B. The last few feet of the lateral pitch down toward the main.

C. With the tops of main and the lateral at the same level, the lateral discharges freely.

Figure 20. Chipping the ends of three tiles to make a junction

Patience and some skill are required to make a good junction this way.

Figure 21. Chipping tile with a monkey wrench

bull-dozer, or in some other way. A painstaking job of binding and blinding pays well in long and satisfactory service.

Exceptions to these general rules of binding and blinding are given in the discussion of surface inlets (page 32), springs (page 27), and laying tile in quicksand (page 28).

Making Junctions

Where one line empties into another, it is best to have the flow of water from the branch or lateral line turned to the same direction as that which flows in the main (figure 19, A). It is also well to lay the lateral so there will be a drop of 1 inch or 2 inches in the last 2 or 3 feet of its length (figure 19, B). Where a larger tile is used in the main line than in the lateral, it is good practice to so lay out the depth of the trenches that the *tops* of the main and the lateral will be at about the same level (figure 19, C).

The best junctions between lines of tile are made with "Y" junction tiles. These usually cost about three times as much as one length of straight tile but, measured in terms of labor for installation and quality of the connection, they are well worth their cost.

If junction tiles are not available, satisfactory connections can be made by carefully chipping the ends of two tiles in the main line and also the tile of the branch line. This may be done with either a light hammer or a monkey wrench. If a hammer is used, the inner edge of the tile should first be chipped. Then with light blows the outer side may be knocked off (figure 20). The use of the wrench is illustrated in figure 21. Any tile cracked in the proccess of chipping should be discarded because such a tile usually fails later. After the three tiles are carefully fitted together, they may be held securely in place by a thick covering of cement and sand mortar made in the proportions of 1 part of cement to 2 or 2½ parts of sand. Only enough water should be used to make the mixture plastic. To prevent the mortar from working through the openings and partially blocking the line, such a junction should first be covered with strips of tough water-resistant paper, such as that used for cement, fertilizer, or lime sacks.

Precautions Against Silting

Silt collects in tile drains for several reasons. Fortunately, however, silting can usually be prevented by care in layout and construction and by simple maintenance practices.

The outlet

Even well-installed tile drains, because of lack of protection of the outlet and failure to clean the outlet annually, may become clogged (page 30).

Junctions

Poorly made junctions may admit fine soil to the lines.

Open joints

Wide and unprotected joints on the top of the line or wide, uncovered joints on the outward side of curves may admit earth to the line (page 19).

Poor grading of trench bottom

An uneven trench bottom on which some tiles are too low and others too high makes pockets in the line where silt may settle (figure 22). Tiles laid on such a trench bottom are also likely to have numerous wide openings at the tops of joints into which earth may be washed.

Figure 22. Tile line correctly laid and laid by eye

Water does not flow smoothly in tile on an uneven trench bottom. Silt may settle in the pockets where the water flows slowly.

Surface inlets

Muddy water, admitted through the surface inlets, is almost sure to cause clogging unless the tiles have a uniform slope throughout the length of the line or the line gets steeper toward the outlet (page 32). Trash that enters a tile line is sure to cause trouble.

Reduction in rate of slope

If the slope of the line is less in the lower part of the line than in the upper part, silt may be deposited. This is most likely to happen if the upper and steeper part of the line is in very fine sandy soil. Under such conditions it is especially important to keep the *outlet clean* (page 43). A masonry catch basin or sand trap may be required (page 34).

Figure 23. An uncompleted job

After trying to plow this field with a wet draw across it, the farmer gave up and waited until later in the season.

Location of Tile Lines

THE location of tile lines has much to do with how well they will collect water from the soil and how effective they will be.

Low Wet Draws

Low wet draws between higher land may delay field operations (figure 23). The logical way to drain these is to lay a line of tile through the lowest part of the draw with branches into any tributaries (figure 24).

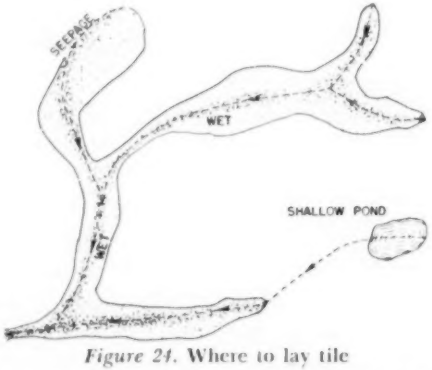

Figure 24. Where to lay tile

Shaded area indicates land that is wet until late spring. Dotted lines show where, in general, tile lines should be laid.

Low Wet Spots Where Water Settles

The location of the tile to drain these spots, for best results and at least cost, depends on (1) the depth of the hollow or sag, (2) the size of the depression, (3) the distance to the outlet, and (4) the height of the land be-

tween the wet sag and outlet. Water that finds its way into such a sag from higher land should, wherever practicable, be diverted so it will not reach the area to be drained.[2]

If the distance to the outlet and the height of the land along the proposed tile line are such that the tile can be at least 2 feet below the lowest place in the sag and not excessively deep in the higher land to be passed through, the tile is best laid through the lowest part of the sag. How to find the depth of the trench and how to lay the tile are given on pages 13 and 19. A permeable fill type of inlet may be needed in such a place (page 33).

Where, because an excessively deep cut would be needed between the sag and the outlet, it is impractical to follow the suggestions offered in the preceding paragraphs, partially filling the sag with earth from the higher land to be crossed by the proposed line may be considered. Another solution may be to place the tile at the side of the deepest part of the sag in land where the trench may not be more than about 6 inches deep. The trench should cut through the sod and to firm earth. A permeable fill type of inlet may be built up (figure 25). The rest of the tile line through the low area should be carefully blinded and then the fill placed to a depth of at least 2½ feet above the top of the tile. The surface must be so graded that the lowest part will be over the permeable fill (figure 25).

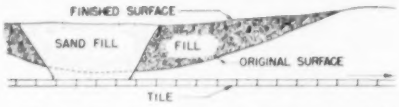

Figure 25. Cross section of a permeable fill type of inlet

Note how the surface is graded to slope toward the sand fill.

The drainage of sags too deep to be drained by this method is discussed under vertical drainage (page 45).

Wet Spots on Hillsides

Wet spots on hillsides are common throughout the Northeast due to natural causes or because old stone drains have been blocked. The most effective way to drain either is with properly placed tile. To place the tile properly, one must find where the water comes from that causes the trouble. If the water comes from an old clogged stone drain, possibly the simplest remedy is to remove the blocked section and relay the drain. Such a wet spot may be drained as suggested under *springs* (page 27). The drainage of wet places that are due to natural causes are discussed in the following paragraphs.

A deep, smooth cut, running up and down the hill made through

[2]Instructions for diverting water from higher land are given in Cornell Extension Bulletin 808, *Diversion Terraces,* by Hugh M. Wilson and Harry A. Kerr.

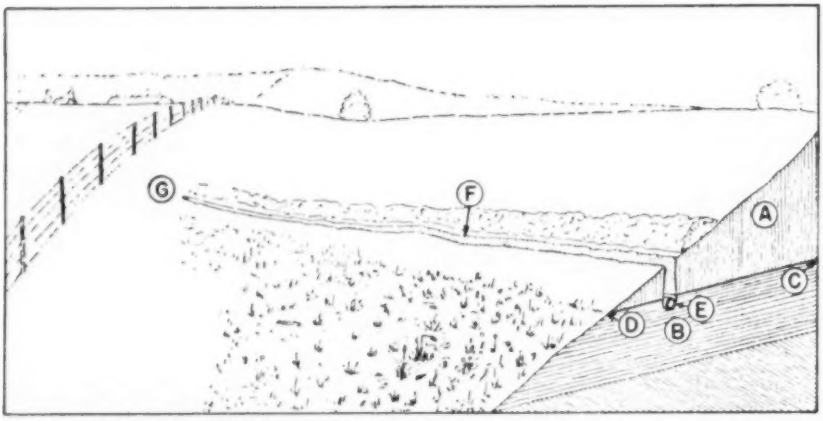

Figure 26. How water finds its way to seepage areas and how this water may be intercepted by a line of tile

such a wet spot would usually show conditions somewhat as indicated at the right of figure 26. The soil in the area *A* is relatively open or permeable so rain that falls on it finds its way down to the tight impervious layer *B*. Water cannot get through this tight layer, so it moves along on top of it, on the line *CD*, and finally seeps out at *D*. How long it continues to come out depends on the character and extent of the overlaying soil *A*.

Because the water which comes to the surface in this way flows down over the surface of the tight soil *(B)*, a large area is usually kept wet by a single seepage line.

Obviously, the way to drain such a place is to lay a line of tile *across* the slope at or just above the upper edge of the wet areas, as in the trench *F*. To be effective, the trench must cut from 3 to 5 inches into the tight subsoil *(B)*. The tile *E* will then intercept the water underground and provide an easy route for it to flow freely to the outlet. If the trench does *not* cut into the tight subsoil, water will flow under the tile and continue to seep out on the surface. Then the job will be a failure.

The tile is most effective when in a trench about 2½ feet deep. The tile should slope at the rate of at least 4 inches in 100 feet of length.

To find just where the trench should be dug saves both time and labor. The simplest way to do this is to bore holes with a soil auger (figure 27) at intervals, up and down the slope, of not more than 50 feet across the upper edge of the wet area. This job must be done when these areas are wet and the rest of the field is dry enough to work, and the holes must be above where the water comes out at *D* (figure 26). Each hole where

water and tight subsoil are found at a depth of 2 feet should be marked with a stake.

The line of stakes thus located indicates the approximate line that the proposed trench should follow. The line may be fairly straight, as from *E* to *G* (figure 26) or it may have several curves. Small adjustments up or down the slope may be made to give smooth curves to the line of the trench.

After the trench bottom has been carefully graded and the tile laid (page 19), the tile may be bound and blinded with sods and topsoil to well above the level of the tight subsoil. The trench may then be backfilled with any earth and stones taken out during digging.

Because the ground water moves down the slope toward the tile, little land above the tile is affected. Since, however, the tile intercepts and carries away the water that would otherwise seep out, the drain affects the land for a considerable distance below the line. Usually one line of tile corrects the trouble on the whole lower part of the slope.

Water from other layers of tight subsoil may, however, come out at lower levels on the slope. If it does, one or more lines must be placed just above these places in the same way as described. When water from above is flowing over the surface, it is impossible to tell whether or not water is coming out at lower levels. ***One should, therefore, always start a hillside drainage job with a line at, or just above, the highest wet area.***

The shape of the hill, the relative height of the seepage places, the slope required for the tile, and the direction in

Figure 27. A soil auger
This is made by welding a pipe to the shank of carpenter's auger. One of the extensions for deep boring is 4 feet long; the other is 8 feet.

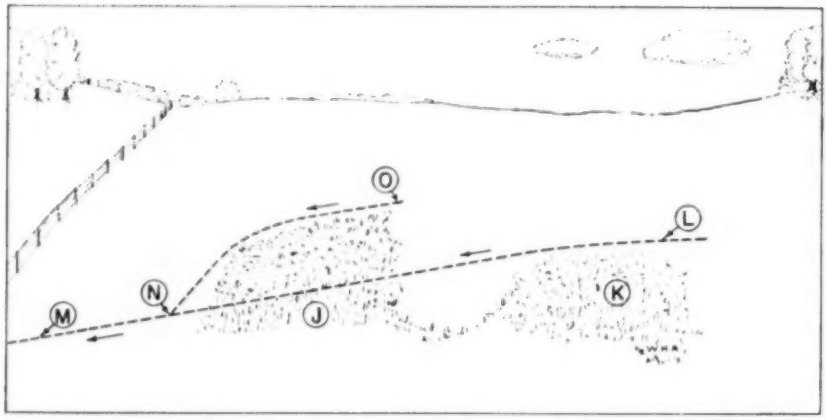

Figure 28. Locations of tile lines to drain seepage areas at different heights on a slope

which it is desired to have the water flow in the tile, may make it impossible to drain more than one wet area with a single line as here described.

Where there are two or more separated seepage areas at different levels, as at *J* and *K* (figure 28), a line *(ML)* may be run along the upper edge of the lower area *(K)*. A lateral, as *NO,* may then be run to collect the water at the upper edge of *J* and deliver it into *ML* at *N*.

Seepage spots in little valleys or draws may be cut off with short lines that cross the draw as *US* and *VS* (figure 29). Both of these lines slope toward *S*. If this seepage area is so low that the tile could not pass through

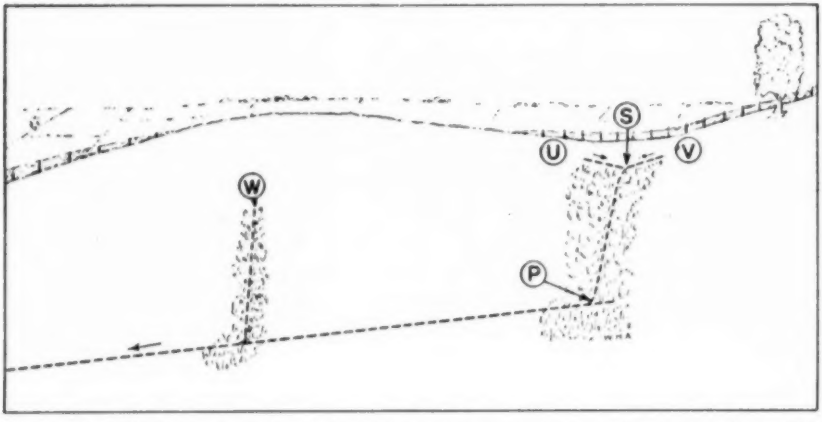

Figure 29. A drain for a spring (W) and for a seepage area along the seepage line (UV) All of the water from such places can be conducted away, underground, through tile.

a spring that may be at *W*, a branch line may be run up the slope to the spring from the line to the outlet.

Springs

To drain a spring from which the water comes out at a definite spot, as at *W* in figure 29, it is good practice to run the line directly up through the spring to where the water is found at a depth of about 2½ feet. The line should be bound and blinded with fine gravel to a depth of about 1 foot for a distance of from 6 to 8 feet. The gravel permits the water to move along the outside of the tile to enough joints to admit all of the water. After the gravel is in place, the trench may be filled with any soil.

Sand Pockets

While the situations just described are the most usual, wet places on hillsides sometimes result from layers or pockets of sand of widely varying depth. These are most effectively drained by laying lines of tile across the slope and through these pockets. As in other types of hill drainage, the work should start, so far as possible, at the top of the slope and the drains should be run across the slope.

The best time to find the correct locations for hillside drains is in the spring of the year, while water is coming from seepage areas and the surrounding land is relatively dry. It is good practice to decide then where the lines should be placed. These locations may be marked with firmly driven stakes. The trench may be dug and the tile laid when the condition of the soil and farm work are favorable.

Figure 30. A small diversion ditch through pasture land to keep surface water off of crop land

White dots show course of the farther part of the ditch. Here no other form of drainage was required.

Wet Areas at the Foot of Steep Slopes

A wet area is sometimes found at the foot of a steep slope. Here again the first problem is to find where the water comes from. It may be mainly from surface runoff from the higher lands (figure 30). Some of the water may be from seepage at the foot of the hill. Regardless of where it comes from, the water from the higher ground should be diverted so it cannot reach the more level land.[3] If the lower land remains wet after the diversion terrace is made, seepage is evidently the cause. This indicates the need of a tile. Here, again, the line of tile should be along the upper side of the wet part of the more nearly level area. Permeable backfill over the tile in this location is important. Several inches of fine bank-run gravel, with sods and topsoil nearly to the top of the trench, all help to insure that the water moving from the hill-will be intercepted and settle quickly to the tile.

Laying Tile in Quicksand

VERY fine sandy subsoil is occasionally encountered in tiling. Such earth is readily moved by water. This kind of soil with an excess of water is commonly known as *quicksand*. It is very unstable. If such subsoil is known to be present, drainage should be attempted only at the end of a long, dry period.

The whole job of laying the tile and backfilling the trench in such soil should immediately follow digging. It is good practice to have no more than 10 or 12 feet of trench open at any time, because the trench banks might slide in or the trench bottom might be forced upward by the earth pressure on this unstable subsoil. When the job is interrupted, as at the end of the day, the work should be completed as far as the digging has progressed and the end of the tile temporarily closed. The tiles are best laid with a tile hook, which helps to prevent tramping the unstable trench bottom. The individual tiles must here be laid with the smallest possible openings at the joints.

Binding (page 19) should be done with earth other than fine sand. There is nothing better for blinding tile than sod. If sod is not available, the tile may be covered with loose straw or with some similar material before the shoulders of the trench are broken in. Where the fine sand comes nearly to the surface, it is best to bind and blind the tile with coarse sand or bank-run gravel. This tends to filter out the very fine material that would otherwise flow into the tile at the joints.

In hand-digging a trench, the tramping on the trench bottom is likely

[3]Modern ways to make diversions are explained in Cornell Extension Bulletin 808, ***Diversion Terraces,*** **by Hugh M. Wilson and Harry A. Kerr.**

to make it too soft for a bed of tile. Bituminized pipe is particularly well suited for these locations, because it comes in 8-foot lengths and has collars that hold the abutting ends in alignment. If tile are used, they may be laid on straight 1-by-6-inch boards. Narrow strips nailed to the boards (figure 31) hold the tile in line and provide a three-point support for them. The tile should be bound and blinded, and the trench filled as described in the preceding paragraph. In this wet location the boards will last for many years and will have served their purpose long before they decay.

The drainage water from quicksand is sure to carry some fine sand, so it is important that the line have a uniform slope or that it increase in steepness toward the outlet. If the rate of slope of the line must be decreased, a silt basin or sand trap is needed (figure 42, page 34).

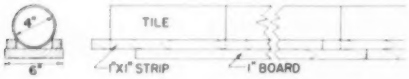

Figure 31. Cross section of boards and strips on which to lay tile through quicksand

The strips prevent tile from rolling and provide added support for it.

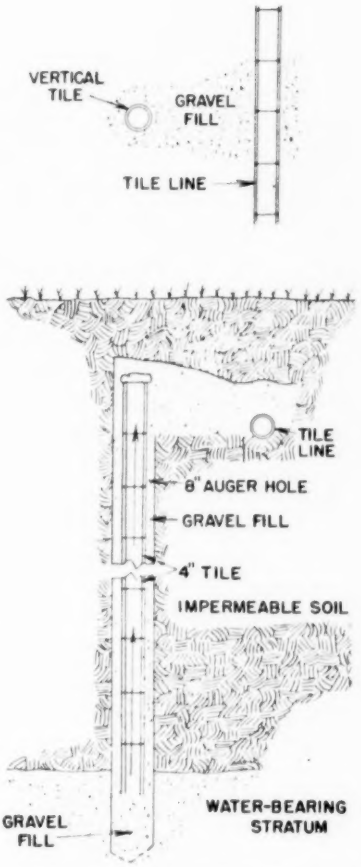

Figure 32. Horizontal and vertical cross sections of a relief well

The vertical tile should not be connected directly to the field line.

Relief Wells

OCCASIONALLY, one finds wet areas on slopes and on flat land that do not respond to the more usual methods of drainage. In such places, the ground may continue to be very wet close to a good ditch or to a well-installed tile line. Usually the cause of the trouble is due to underground water that is under enough pressure to force the water up through even a very dense subsoil.

Here the first job is to find how deep the source of water is. The next step is to install relief wells through which the water can come easily up to the level of the drain tile.

A relief well (figure 32) is merely a permanent hole that is deep enough to reach down into the ground water that is under pressure. To find the depth of the real source of water, borings are made with a soil auger. Extra sections may be needed in the handle of the auger because the holes may have to be 10 feet or more deep. The need of a relief well is indicated when the borings pass through dense soil, finally enter sandy or gravelly subsoil, and water from the bottom soon fills the hole.

A relief well can be made by boring a hole with an 8-inch post hole auger (figure 33). Extra sections, one about 4 feet and another 8 feet long, may be needed on the auger shaft. The hole is bored to a depth of at least 1 foot below where the water is found. After all loose earth has been carefully removed, four or five shovelfuls of fine gravel are poured into the hole. Enough 4-inch tile to reach to about 18 inches from the surface are now let down with a metal hook or a pole with a spike through it. The hook or pole must be long enough to reach to the bottom of the hole. Tile should never be dropped, as they crack or break easily. The tile are aligned with the hook or pole so the column is straight, then fine gravel is placed all the way around the outside of the tile so as not to push the pieces out of line. A flat stone is placed over the tile as a cover (figure 32).

The field tile and the relief well should be about 1 foot apart, as indicated in figure 32 (page 29). The tile in the well will probably settle. If there were a rigid connection between the tile in the relief well and the tile to the outlet, the line to the outlet would be damaged.

Supplemental Structures

Head Walls and Metal Pipe at Outlet

TILE, exposed at the outlet of a line, may be broken. The tiles are only a foot long so may be moved easily if they are not well protected. Water from the tile that falls on earth is almost sure to form a hole into which the end tile may drop.

A firmly placed flat stone on which the water will fall helps to prevent undercutting (figure 34). A headwall of well-laid stones gives added protection (figure 35). Cast iron or corrugated culvert pipe or old boiler flue makes excellent outlet ends for tile drains. The pipe should be at least 8 feet long. It should preferably be the same diameter as the tile. If the line discharges into a stream, the pipe should be long enough to

Figure 33. A post hole auger

The pipe handle extensions are 4 feet and 8 feet long. They are used for deep boring.

Figure 34. A rough but effective headwall at outlet of a 4-inch drain

The flat stone on which the water falls prevents it from making holes. Bars keep small animals out of tile.

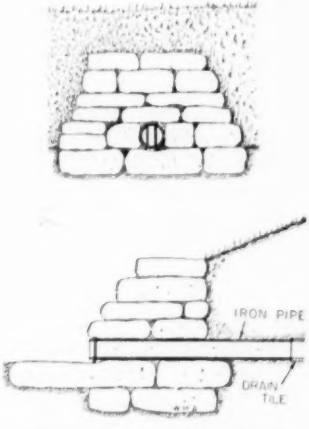

Figure 35. A good headwall

Above: face of outlet showing animal bars. *Below:* cross section showing iron pipe and large stone on which water falls.

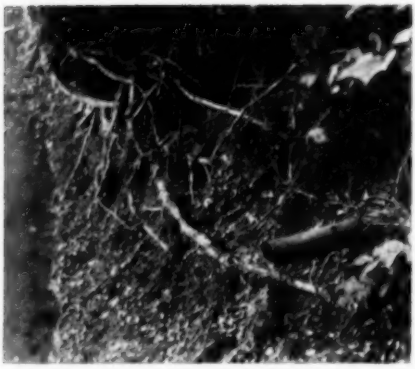

Figure 36. Iron pipe used as outlet for 4-inch tile

This extends about 4 feet out of a steep riverbank. It is so high above the ground that there is little danger of animals getting to it.

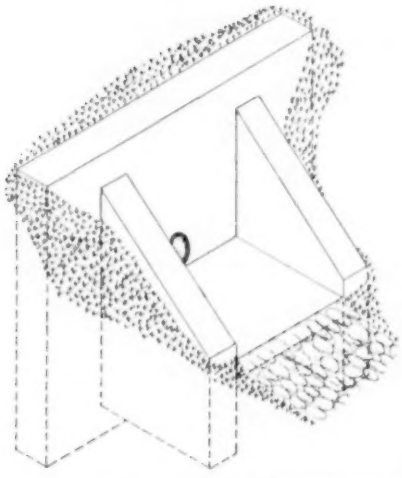

Figure 37. A good type of concrete headwall

The wing walls act as braces, and also prevent banks from sliding and thus blocking the outlet.

provide firm anchorage in the earth and extend out over the water of the stream (figure 36 and cover illustration).

A concrete wall is needed (figure 37) if good stones for building the headwall are not available. Such a wall must have a deep foundation and wing walls so it will not be pushed over. A notched concrete head wall is needed (figure 38) where a grassed waterway and a tile drain (page 35), discharge at the same place (page 36).

Corrugated pipe to the end of which is fitted a flap gate is on the market. Such gates close tightly when the water in the stream rises above the outlet of the tile lines. They are useful also as animal guards (page 35), but their usefulness is generally limited to lines that outlet into streams that flood for a short time after heavy rains. They are expensive and they tend to retard discharge under normal conditions.

Surface Inlets

In low places, where water tends to collect, it may be desirable to provide surface inlets to let the water get to the tile faster than it will pass through the soil of the field. The best surface inlet is merely a permeable fill over the tile. In extreme cases masonry structures covered with a grating may be used. The permeable fill is much simpler and cheaper to build and maintain and, in general, is more satisfactory.

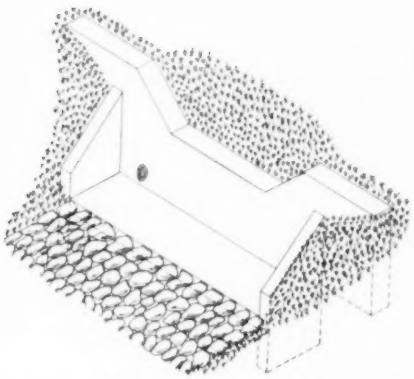

Figure 38. Concrete head wall for outlet of a grassed waterway and tile

The notch concentrates the surface water and spills it on to the concrete apron. Bars at the tile outlet keep animals out. See page 35.

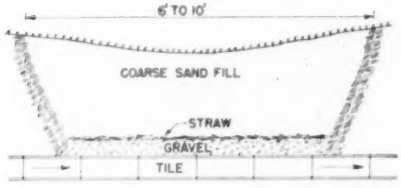

Figure 39. Cross section of a simple permeable fill surface inlet

Sand makes the best fill for the upper part of such an inlet. It filters out the silt better than do stones or coarse gravel.

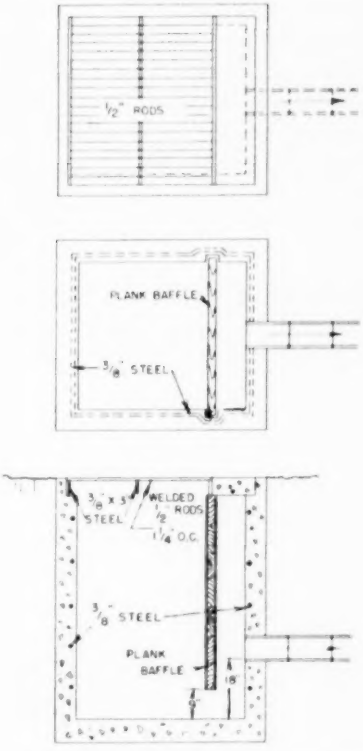

Figure 40. Plan and cross sections of a masonry inlet.

Note the depth of the box and the baffle. They help to keep earth and sticks out of the tile.

Permeable fill inlets

Such a fill is best made by placing bank-run gravel to a depth of about 6 inches over the tile as soon as it is laid. This serves both to bind and to blind the tile. The gravel is covered with straw, weeds, or low-grade hay. The trench is then filled with coarse sand (figure 39). The length of such a fill seldom needs be more than a rod. If the sag is long, two or more such fills are needed at intervals of 40 to 50 feet. Obviously, the earth that came from the ditch at these places will have to be pushed back and spread over the other low parts of the field.

Masonry inlets

A masonry surface inlet, to be effective and durable, must be carefully planned and well built. It must be deep enough to extend at least 18 inches below the bottom of the tile and be large enough to be easily cleaned (figure 40). To be of real service it must be cleaned regularly (page 43). The top must be fitted with a coarse, strong screen or grating (figure 41) to prevent sticks, stalks, and straw from getting into the tile. The baffle helps to prevent sticks from getting into the tile.

An inlet of this kind obviously interferes with some field operations. For this reason, it should, if possible, be placed in a fence line where it will be most out of the way and more nearly safe from damage. Wherever possible, the land above such inlets should be kept in sod.

Silt Basins or Sand Traps

A silt basin or sand trap may be needed where the rate of slope of the tile line must be reduced. Carefully grading the trench bottom, use of tile of adequate size in the more nearly level parts of the line, and *keeping the outlet clean* all tend to reduce the need of such a structure. If, however, the steeper part of the tile line passes through quicksand for a con-

Figure 41. A good type of grating for a surface inlet

The heavy bars are parallel to the direction of the flow of surface water. Placed in this direction the bars tend to be washed clean rather than to hold trash.

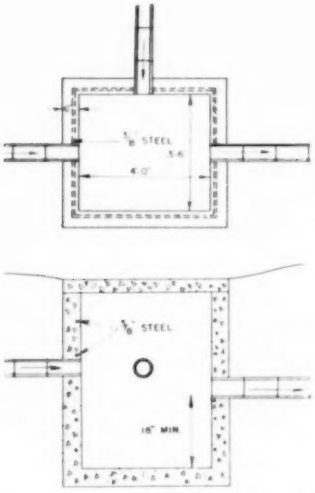

Figure 42. Cross sections of a concrete silt basin or sand trap

A sand trap is seldom needed. If one is installed, it should be cleaned regularly.

siderable distance, the silt basin is more essential. Much of this fine sand is sure to enter the line. It will be dropped wherever the velocity of the water is much reduced and may soon block the line. Cross-sections of a sand trap are shown in figure 42. Because the water moves slowly in the large area of this trap, the heavier soil particles settle there, leaving nearly clear water to go on down the tile. The trap must be deep enough to hold this deposit. To be successful, it must be cleaned before the accumulation reaches the outlet tile. Like the masonry inlet, it should, if possible, be placed where it is out of the way and not subject to damage.

Small-Animal Guards

Small animals, such as muskrats, rabbits, skunks, and woodchucks, may enter subsurface drains and may build their nests in large tile. Because they cannot turn around in small tile, they work their way up the line until they are exhausted and die. The remains of such animals have been removed from blocked tile as far as 200 feet from the outlet. Any obstructions of this kind tend to slow the flow of water and silt may be deposited and finally block the line. The outlet of all tile drains should, therefore, be fitted with a secure guard of heavy or coarse mesh screening or metal bars (figure 43 and cover illustration).

Figure 43. Small animal guards

The bars at the end of the drain keep out muskrats, rabbits, and skunks. See also cover illustration.

Tile Drains and Grassed Waterways

SURFACE runoff from higher land should, wherever practicable, be diverted from the lower cultivated land.[4] Where, however, surface water must cross the field and the volume of flood water is too great to be carried in a tile of reasonable size, a combination of a 4- or 5-inch tile and a grassed waterway is satisfactory (figure 44).

The surface course must be wide and deep enough to carry any usual flow. The sides should be so graded that the waterway can be readily crossed with farm implements, the banks must be pushed back and graded

[4]Instructions for diverting water are given in Cornell Extension Bulletin 808, *Diversion Terraces*, by Hugh M. Wilson and Harry A. Kerr.

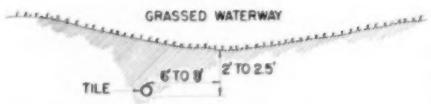

Figure 44. Cross section of a grassed waterway and tile

The surface depression carries flood water, and the tile takes off the excess ground water after the flood.

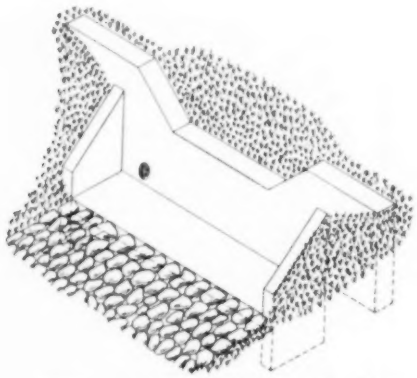

Figure 45. Headwall suitable where grassed waterway and tile must discharge at same place

so water will not collect behind them, and the bottom so graded that water will not collect in large pools.

Where the slope of the course is more than about 12 inches in 100 feet of length, the tile should be laid from 6 to 8 feet to the side of the bottom of the course (figure 44). If practicable, the course or the tile, or both, should be so turned near the lower ends that they will not outlet at the same point. If this cannot be done, a head wall with a broad notch (figure 45) is needed to protect the ends of both the tile and the surface-water course. Danger of damage due to heavy rains while the grading and tiling are in progress may be reduced by building the head wall first. A pipe to form the outlet of the tile must naturally be installed during the progress of this construction.

After the tiling and grading have been completed, the course should be thoroughly harrowed, well fertilized and, with a nurse crop, seeded to a permanent grass.

Protection Against Roots

TILE drains may be blocked by roots. Water-loving trees and brush, such as willow, white elder, tag alder, poplar, elm, and soft maple, are the worst offenders. Tile that carries water most of the year, as those that drain springs and seepage areas, are the ones most likely to be blocked.

The only practical prevention is to destroy all trees and brush that have branches spreading to within 30 feet of the tile lines. Trees and brush, including their roots, may be killed by cutting in August. Brush and small trees may also be killed with chemical sprays.

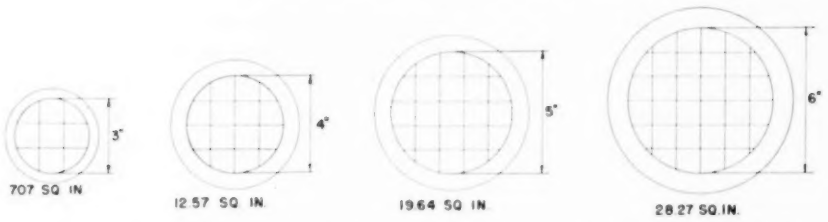

Figure 46. Number of square inches in the more common sizes of agricultural tile

Note how greatly the capacity of tile is increased by a relatively small increased diameter.

Selection of Tile

Size

THE size of the tile needed naturally depends on (1) the amount of water that it will be required to carry and (2) on the slope and condition of the line. Except where large springs are to be drained or there is known to be excessive amounts of water in a permeable subsoil, 4-inch tile is commonly used in the Northeast to collect the ground water. For lines that slope at the rate of 6 or more inches to each 100 feet of length and which are no more than 800 feet long, well-laid 3-inch tile in a properly graded trench are, however, satisfactory. Larger tile will not compensate for poor workmanship. Obviously, larger tiles are needed to carry large amounts of water, as where masonry surface inlets are used, especially on the flatter slopes where the water flows more slowly.

The area and, therefore, the carrying capacity of tile increases rapidly with increase in diameter. This is illustrated in figure 46. A drainage engineer can recommend the sizes of tile required for various places.

Shape

Six-sided or hexagonal tile, circular on the inside, are occasionally found. The advantage claimed for them is that they will not roll and can, therefore, be kept in a better line.

Round tile can be turned to any degree that makes them fit best. They will not roll if the trench bottom is rounded, as it is left with a power trencher (page 40) or as may be done with a tile scoop (figure 11, page 16). Most of the present-day tile are round.

Condition or Soundness

For a successful job, all tile must be sound when laid. A cracked tile is

likely to fail under the weight of the earth and other loads. One should tap each tile with a hammer handle or with some similar piece of hard wood to determine its soundness. Sound tile gives a clear metallic ring. If a perfect tile and a cracked tile are tapped alternately, the difference in sound produced by the good and by the defective tile is easily recognized.

Quality

Tile should be strong and so dense that they absorb little water. The American Society for Testing Materials, in cooperation with other organizations, has set up standards for agricultural tile and furnishes instructions for making tests. Buyers should insist on tile that meets these specifications, and sellers should be prepared to furnish evidence that the tile they deliver is of this quality.

Digging the Trench

Figure 47. A trench or tiling spade

Note the narrow blade with round point.

REGARDLESS of how the earth is removed from the trench, the bottom must be finished to an even grade. The only reason to have the trench wider than the outside diameter of the tile is to make hand digging possible.

Hand Digging

Hand digging is economical only for short lines. Loosening the earth for at least part of the depth with a walking plow, or better, with a subsoiler or a rooter, hauled with a chain or cable, lightens somewhat the labor of hand digging. Occasionally, one can find an old "ditching" plow which is excellent. A trench from 2½ to 3½ feet deep dug by hand must be from 14 to 16 inches wide throughout most of its depth to provide room for a man to work. The earth from the narrower bottom of the trench may be removed with a trenching or tiling spade (figure 47).

Grading the trench bottom "by eye" is not a dependable method. Grading "by water," when carefully done, and on slopes as steep as 8 to 12 inches in 100 feet of length, may give fairly good results. On lesser slopes this method should seldom be attempted, for some parts of the bottom would be too steep and others

too nearly flat, and some parts may even slope in the wrong direction.

Where there is not much fall and where the surface is uneven, the line should be surveyed (page 44). The engineer should set stakes about 3 feet to the side of the centerline of the proposed trench and at intervals of 50 feet. In each location there should be a hub stake, the top of which is practically even with the surface of the ground (figure 48). There should be a witness stake close to each hub stake so the hub stake can be readily found. The engineer determines the depth that the trench bottom is required to be from the top of each hub stake and indicates this depth or cut on the corresponding witness stake.

When the trench has been dug nearly to the required depth, batter boards and a grade line may be put up as shown in figure 48.

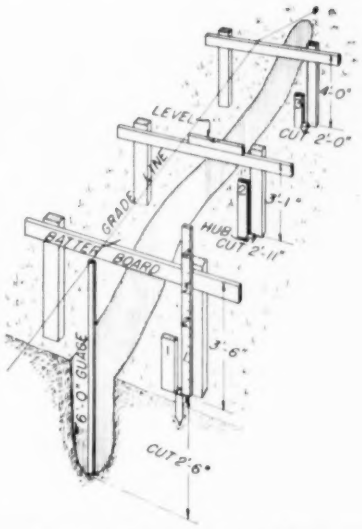

Figure 48. Hubstakes, marked witness stakes, batter boards, grade line, and gauge stick

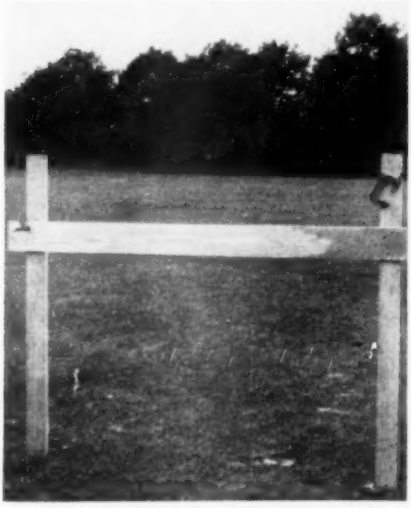

Figure 49. Batter board held to uprights, at left, by "C" clamp

At right, side view of "C" clamp.

It is usually convenient to have the grade line 6 feet above the finished trench bottom; therefore, the tops of the batter boards must be at a height equal to the difference between 6 feet and the depth of cut, measured from the top of the hub stake. The top of each batter board must be level. The boards may be nailed to the uprights or may be held in place with "C" clamps (figure 49).

If much work is to be done, a rod like one of those shown in figure 50 is helpful. Such a rod eliminates most of the danger of errors in setting the batter boards. To use

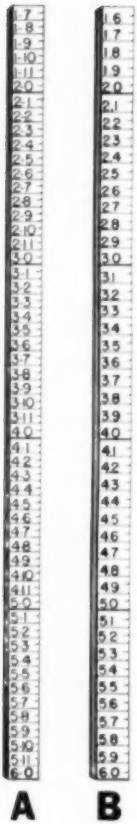

Figure 50. Self-calculating rods for measuring from hub stakes to batter boards

A. The feet are divided into inches.

B. The feet are divided into tenths of feet.

such a rod, one places the top of the batter board at the rod reading that is the same as the depth of the cut; therefore, no computation is required when such a rod is used.

It is customary for the drainage engineer to use feet and tenths of a foot, rather than feet and inches, in making his measurements and computations. If the cuts are marked on the stakes in feet and tenths, the rod should be marked like the one shown in figure 50, B.

The trench is graded by making it just deep enough so a 6-foot gauge stick will reach from the grade line to the trench bottom.

Batter boards in place over a ditch are shown in figure 51. How the field shown in figure 51 looked a year later is shown in figure 52.

Machine Digging

Digging a trench is heavy work and, therefore, requires a heavy and strong machine. The trench must be finished to a suitable grade. If the final grading is to be done with the machine, the machine must be one that can be readily controlled to dig at various depths and to dig at the right depth all the time. A good type of trenching machine is shown in figure 53. The long wheel base prevents such a machine from "bucking" or rocking up and down as it moves over uneven ground. The digging is done by the large wheel at the back. This digging wheel is mounted in a frame that can be moved up and down by the operator, using power supplied by the engine.

The operator keeps the grade by sighting over a bar on the digging wheel frame and over a line of targets as shown in figure 54.

The targets are placed at the required height with reference to the tops of the engineer's hub stakes, in the same way that batter boards are located for the grade line (page 15). A good operator, under reasonably good conditions, can dig a trench to grade and, if necessary, as deep as 5½ feet, with such a machine. The trench has vertical side walls and the bottom is rounded ready to receive the tile.

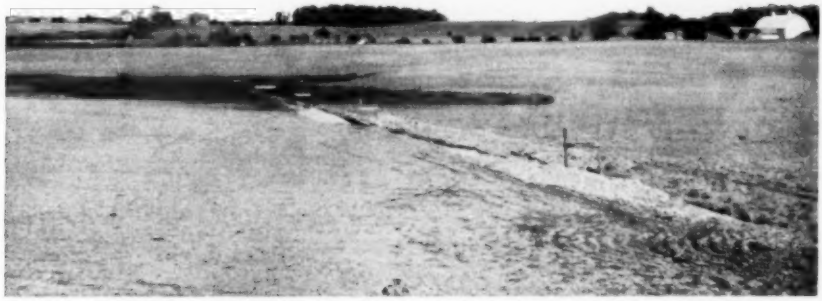

Figure 51. Batter boards and grade line over a trench for tile to drain a wet spot in an otherwise good field

Note the part of the trench at right; tile has been laid and backfilling completed. See also figure 52.

Figure 52. This picture, taken two years after the one in figure 51, shows the change the tile made

Now, after 20 years, the water that would have otherwise made the spot wet flows away through the tile.

It is obvious that large stones cause trouble when digging with such a machine. Machines of this type have, however, been successfully used in New York and other States for many years and hundreds of miles of trench have been dug with them in stony soil. In New York State several contractors for drainage work have this kind of equipment. A reliable contractor who renders this type of service is doing a great community service. He should be encouraged.

A disadvantage of any heavy machine is the inconvenience of moving it from job to job. Some drainage contractors have developed simple skeleton trailers onto which the trencher can be easily and quickly loaded for transportation.

Figure 53. A good type of farm trencher

The long wheel base prevents "bucking" as the machine moves over uneven land. The digger wheel is raised and lowered by power from the engine. White arrow points to sighting bar. See figure 54.

Road graders, small back hoes, and other machines have been used to dig trenches for tile with varying degrees of success. The trench cannot be finished to a suitable grade with any of these machines, which means that for a really good job a grade line must be put up and the bottom

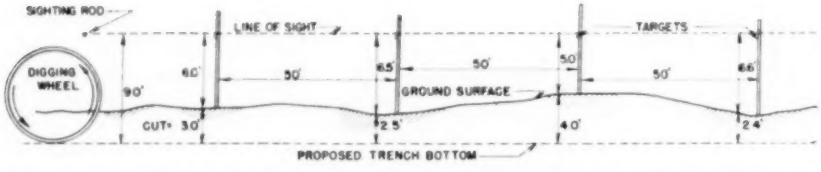

Figure 54. Diagram of digger wheel of a trencher like the one shown in figure 53

The operator keeps the grade by sighting over the sight rod and the targets. Note that these targets are 9 feet above trench bottom. Operator can lower or raise the wheel with power from the engine.

graded by hand labor. The grader, when cutting deep enough for tile, must move a great excess of earth, which must be moved back again during backfilling. No surface soil and sod are available to blind the tile because all excavated material is mixed together and there are no shoulders on the ditch.

The back hoe also moves more earth than is necessary to make a trench of the width required for tile. The handling of excessive amounts of earth with a back hoe may be corrected to some extent by the use of a narrow bucket. In attempting to work as close as possible to the finished grade the operator may get some parts of the trench too deep, which requires extra time and labor to get fine gravel to fill the low places or to compact the earth used to fill them. Fills not so firm as the undisturbed soil are sure to settle later and cause "pockets" in the tile line.

Inspection and Maintenance of Tile Drains

TILE drains carefully planned and well constructed are practically permanent. If, however, they are to give the long service of which they are capable, they must be given a chance to do their job.

Nearly all of the trouble with well-laid tile drains results from ***poorly constructed and neglected outlets*** (page 30). The outlets should be inspected every spring before field work starts and while the lines have water in them. Mud, grass, and weeds should be removed so water can flow away freely. Any damage to the head wall or to the animal guards should be promptly repaired.

Catch basins or sand traps (page 34) and masonry surface inlets (page 34) ***should be cleaned.*** If permeable fill inlets are not removing surface water as fast as when they were first installed, the silt should be cleared, from the surface down to the sand or gravel fill, and replaced with new sand and the surface re-graded.

Any "wash-ins" require attention. These may appear as holes directly over the tile line. They indicate a broken tile, a poorly made junction, or an excessively wide opening between individual tiles. Wash-ins are seldom found after the first year the line is in service. At such spots the tile should be uncovered. Broken tile should be replaced, bad junctions repaired, and cracks covered, as the case may be.

It is obvious that these repairs add somewhat to the cost of the tile-drainage job. If they are needed, they represent but a small proportion of the original cost. Moreover, if the job is well done in the first place, such repairs are seldom needed.

The annual maintenance of a good tile-drainage job is actually small. When compared with maintenance costs of farm implements, it is insig-

nificant. Time and money spent on the maintenance of tile drains is much more than offset by savings on the maintenance of field machinery due to better working conditions. Tile-drainage maintenance work can, and should, be done before the land is suitable for spring work.

The Survey

A SURVEY — that is, the measuring of horizontal and vertical distances and making the necessary computations — should be made before any tile drainage job is attempted. What equipment is needed and how extensive and detailed the survey need be, depend on the area and features of

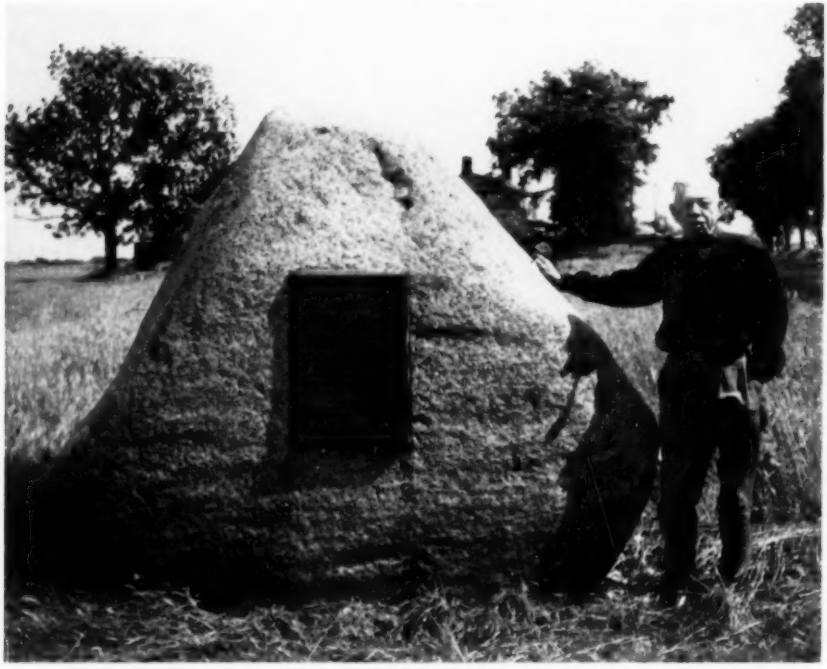

Figure 55. Two "monuments" to tile drainage

At left, boulder and bronze plaque on the Johnson farm near Geneva, New York, where the first tile drains in America were installed. At right, Professor Emeritus B. B. Robb of Cornell University who probably has done more than any other man to advance tile drainage in the Northeast.

The inscription of the plaque reads — "John Johnson (1791–1880) eminent farmer who here originated tile underdrainage in America in 1835 and thereby became an outstanding contributor to human welfare. Honored by The American Society of Agricultural Engineers, 1935. Erected by State Education Department."

The original farm house in which Johnson lived shows in the background.

the land to be drained. The survey for a single short line of tile is outlined on page 13.

Surveying for larger drainage systems is outside the scope of this publication. The County Agricultural Agent can arrange for the necessary surveys for drainage. In making such surveys, one should "take shots" in the low wet spots that are near the original line. The drain should, if possible, be laid at such a depth that drains from these spots may discharge into the original line of tile.

Many of the more or less extensive systems in the Northeastern States have been built up by adding to the original line or simple system. Because many tile drainage systems are extended or added to, it is well to have a careful survey made of the lines as soon as they are put in. Such a survey should have adequate "ties" to buildings, trees, and other permanent features. To be useful, such a survey should result in an accurate map. Though such a map may seem unduly expensive at the time the work is done, it is likely to save more than it costs when in after years extensions are to be made. Often such maps are helpful when property is sold, as they indicate the extent to which the land has been improved.

Mole Drains

So-called mole drains are passages made by drawing a cigar-shaped steel "mole" through the soil. The mole is usually about 3 inches in diameter, it is welded to a ⅝-by-8-inch steel shank which in turn is attached to a carriage similar to that of a tractor plow. As the machine moves forward, the shank leaves a slot or kerf in the soil through which surface water may enter. Every few years the mole drain is heralded as a new, successful, and economical way to improve land. At best, these drains are not effective for more than one or two years. The mole drain has been tried many times in this country, but has not proved successful.

The general objections expressed to this method of drainage are that (1) the machines require an excessive amount of power, (2) the drains can seldom be made with a satisfactory slope, (3) they are subject to silting, and (4) they are readily damaged by the deep freezing of the soils.

Vertical Drains

The purpose of a vertical drain is to let water from a pond hole down through tight subsoil to underlying permeable material. The cross-section of such a drain is shown in figure 56. A vertical drain may be successful if conditions are favorable and the job is well done. Many attempts to use such drains have, however, resulted in complete failure. This indi-

cates the importance of studying conditions before going to the expense of making such a drain.

To find whether such a drain might be successful it is necessary to:

1. Find the relative elevations of the bottom of the pond hole and the top of the water in any nearby swamp or pond.
2. Make borings with the soil auger (figure 27, page 25) to find whether there is sand or gravel at a depth to which it is practical to dig or blast a hole.

If there is gravel or sand at a reasonable depth and the bottom of the pond hole is at least 2½ feet higher than the surface of nearby water, the chances are generally favorable for success. There is, however, always the possibility that the underlying gravel may be full of water during some seasons and will not receive more when drainage is most needed. There are places where water has come up from the gravel and made conditions worse than they were originally.

To make a vertical drain, one digs down to the gravel or sand; fills the hole to within about 3 feet of the surface with small stones or bank-run gravel; covers this fill with straw; fills the hole with coarse sand to the level of the *finished* surface, and then spreads the earth taken out in digging the hole so the finished surface slopes toward the sand fill (figure 56). The sand fill insures longer useful life than do stones or gravel. The *entire* fill may be made with coarse sand.

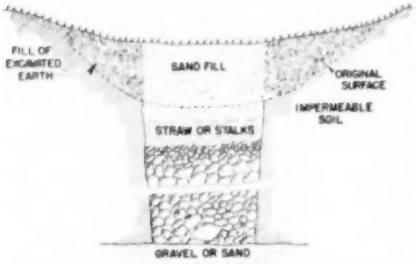

Figure 56. Cross section of a vertical drain showing previous fill and surface grading

Surface Drainage or Bedding

In certain areas of New York and other Northeastern States, some soils are so tight or impervious that water passes down through them very slowly. Many of these lands are so nearly level that surface runoff also is slow. It is usually impossible to get a good outlet for deep, open ditches. For these reasons, neither tile nor open ditches are satisfactory.

The most effective way to improve the drainage of such tight, flat land is to plow it in backfurrows or beds (figure 57). The backfurrows should be spaced so even numbers of rows of corn or other row crops can be planted between them. They may be from 30 to 60 feet wide. Several plowings may be required to work the backfurrows up to the required height.

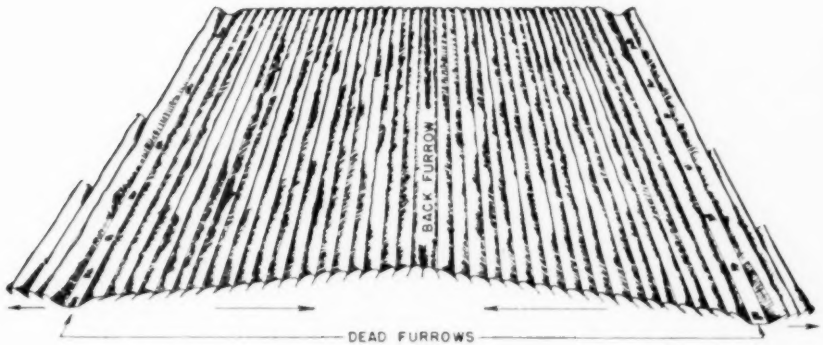

Figure 57. Cross section of beds made by backfurrowing

Two or three plowings may be required to build the beds to suitable height. Arrows indicate direction in which furrows are turned.

Surface water finds its way down the slightly sloping sides of these beds to the dead, or "out," furrows. From these dead furrows the water must be conducted through a shallow ditch across the end of the field to a suitable outlet. In such an arrangement, the dead furrows must be kept clean and water must have an unobstructed flow all the way to the final outlet.

After beds have once been made, they may be maintained at suitable heights by turning all the furrows in each bed in the same direction. The direction of turning should be reversed at alternate plowings. There is little occasion to plant the dead furrows as practically nothing will grow in this wet subsoil. Crops will naturally be best at the middle of the beds where the soil is deepest, the surface is highest, and the drainage is best.

It is obvious that some land will be lost for crop production where this method is followed. Where the system is carefully practiced, however, the better crops on the beds more than offset the reduction in area planted.

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